Status of WRF and WRF 4DVAR and its application within the SPP1167 project COPS-GRID

Thomas Schwitalla[1], Hans-Stefan Bauer[1], Florian Zus[1], Matthias Grzeschik[2], Volker Wulfmeyer[1]

[1]Institute of Physics and Meteorology, University of Hohenheim
[2]Laboratoire d'Aerologie, Toulouse

Motivation Quantitative Precipitation Forecasting

- Precipitation has a strong influence on our economy and general livelihood.
- Especially, the forecast of small-scale severe precipitation events is among the most difficult tasks in meteorology.
- Radiosondes and passive remote sensing are the major source of observations used operationally.
- More sophisticated observing systems, e.g., lidar, radar, or GPS, will be available operationally in the future.
- However, interfaces between the observations and the assimilation systems are hardly available yet.

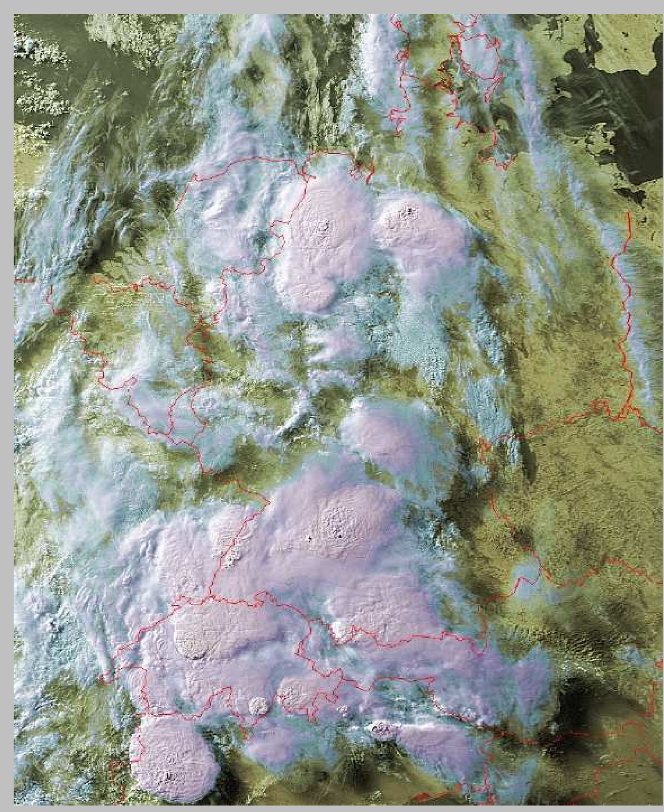

Figure 1: Severe Weather situation in Germany.

Hypothesis

Short-range QPF is significantly improved by the assimilation of high-resolution observations of the 4-d distribution of water vapor, temperature, and wind.

Status of WRF and WRF 4DVAR

- Current release is WRF V3.0.1.1 from August 2008
- New 2-moment cloud microphysics scheme available since WRFV3
- Direct use of ECMWF model level data (including cloud water+cloud ice) to reduce interpolation errors
- Possibility to run WRF as a global model with user specified resolution
- WRF 3DVAR system in version 3.0.1.1 released in August 2008
- Operators for upper air observations, surface observations, GPSPW, GPSREF,GPS ZTD, satellite observations (winds and radiances), and radar measurements (reflectivity and radial velocity) available in the 3DVAR system
- Quality checks are performed for outliers in a user specified range
- Surface observations are rejected if the observation is more than 100m below or above model topography
- The user can define observation types used for the assimilation via namelist
- Background Error covariance matrix not diagonal as in MM5 3DVAR/4DVAR
- WRF 4DVARsystem still in beta status
- 4DVAR will contain the same operators as 3DVAR including full vertical diffusion
- Official release of 4DVAR is planned for March 2009 with WRF 3.1

Comparison of MM5 and WRF

The WRF model system developed by NCAR is the successor of the MM5 whose development was frozen in 2004. It contains improved physical parameterizations originating from MM5 as well as completely new developments. The WRF/WPS model package contains preprocessors for various input datasets and the model system is optimized for scientific as well as operational applications. The WRF system at ECMWF runs more than three times faster than the MM5.

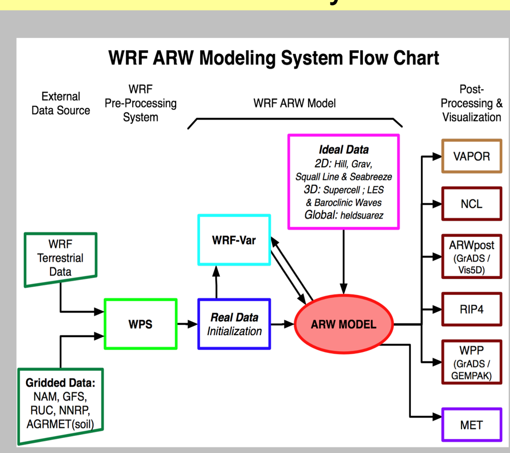

Figure 2: Flow chart of the WPS/WRF model package.

	MM5	WRF
Time Integration	Leapfrog	Runge-Kutta
Timestep	3*dx	6*dx
Digital Filter	no	yes
Global runs	no	yes
MPI	yes	yes
OpenMP	yes	yes
OpenMP+MPI	no	yes
GPU capability	no	yes
Adaptive timestep	no	yes
Moving nests	yes	yes
direct use of ECMWF model leve data	no	yes

Figure 3: Comparison of various features of MM5 and WRF.

WRF Physics test for IOP 14b

Model configuration:

- 1 single domain with 10km (300*300 boxes) resolution to avoid nesting problems
- 40 vertical levels up to 100hPa
- KF-ETA cumulus scheme
- NOAH Land-surface model
- Boundary layer scheme either YSU-PBL or MYJ-PBL
- Thompson or new 2-moment cloud microphysics scheme
- Initialization from ECMWF Model level data at 18UTC on August, 8th, 2007

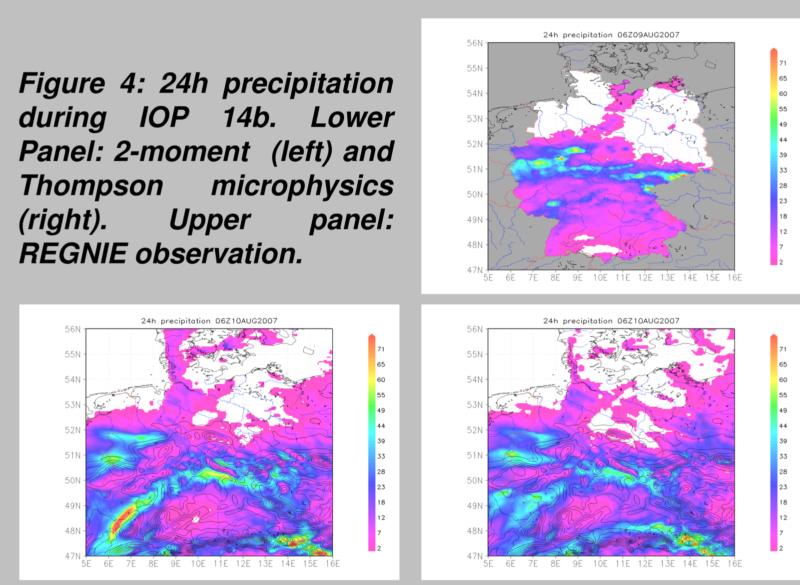

Figure 4: 24h precipitation during IOP 14b. Lower Panel: 2-moment (left) and Thompson microphysics (right). Upper panel: REGNIE observation.

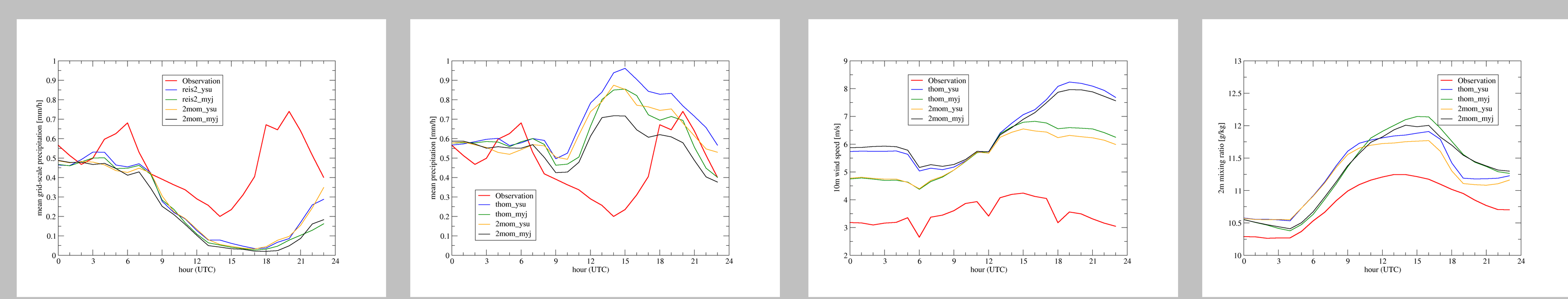

Figure 5: From left to right: diurnal cycles of grid-scale precipitation, total precipitation, 10m wind speed and 2m mixing ratio compared with SYNOP observations (red lines).

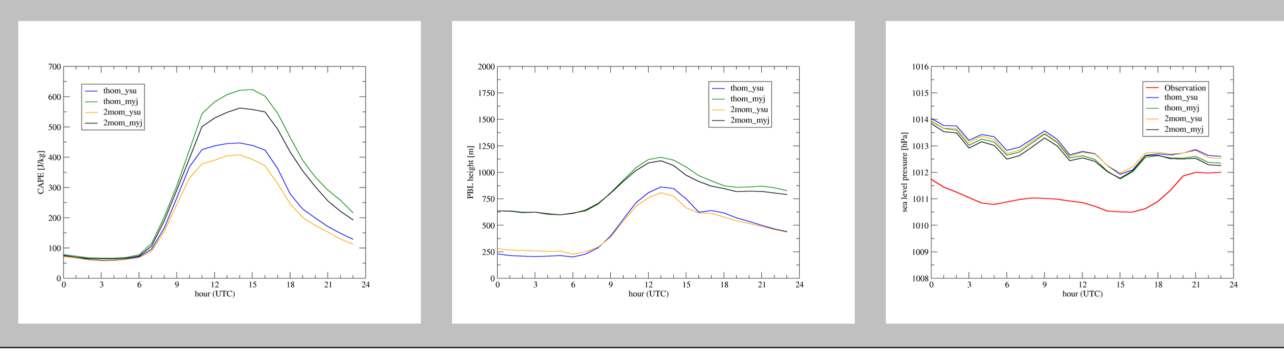

Figure 6: Diurnal cycle of CAPE (left panel), PBL height (middle panel) and sea level pressure (right panel).

First intercomparison of MM5 and WRF for COPS IOPs 8b,9c

Since it is the aim to switch from MM5 to WRF for impact and process studies, a first important step is to compare the forecasting performance of MM5 and WRF for well documented COPS IOPs.

Model configuration for MM5 and WRF:

- 3 domains with 18-6-2km resolution with 2-way nesting
- 36 vertical levels up to 100hPa
- KF2/KF-ETA cumulus scheme on 18 and 6km
- MRF/YSU-PBL scheme and Reisner2/Thomson cloud microphysics
- 5-layer soil model/NOAH-LSM (WRF)
- Initialization from ECMWF model levels (including cloud water and cloud ice) at 00 UTC

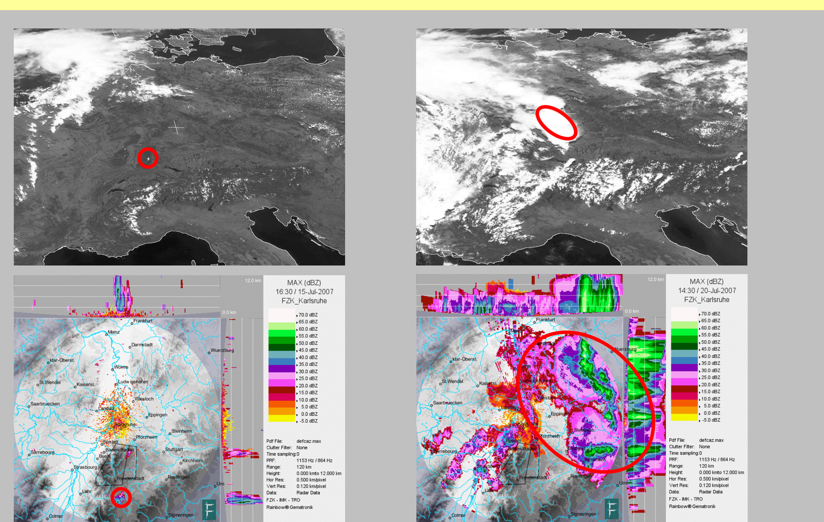

Figure 7: MSG HRV Images (top) and corresponding radar reflectivities (bottom) from 12 UTC of IOP 8b (left) (air mass convection) and IOP 9c (right) (forced frontal convection).

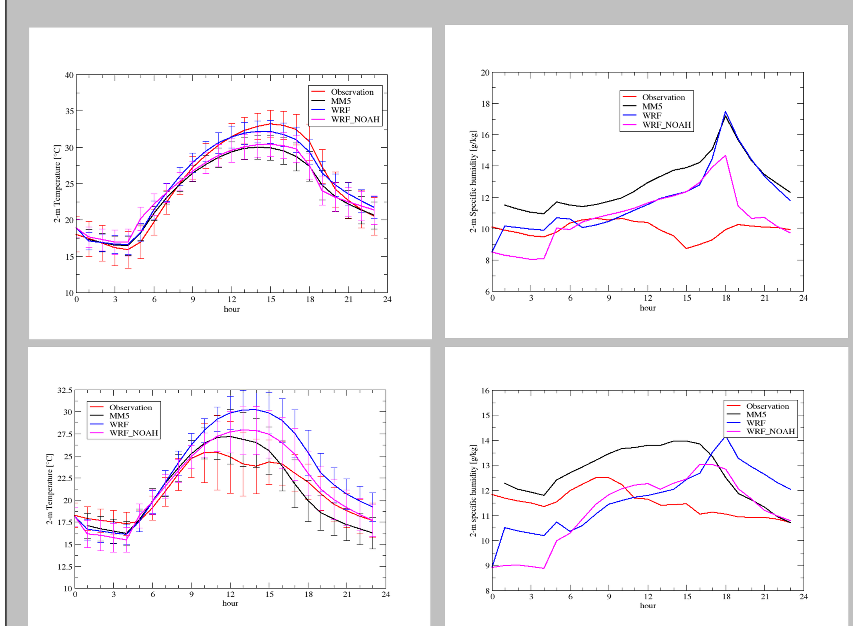

Figure 8: Diurnal cycle of 2m temperature and humidity for IOP 8b (top) and IOP 9c (bottom).

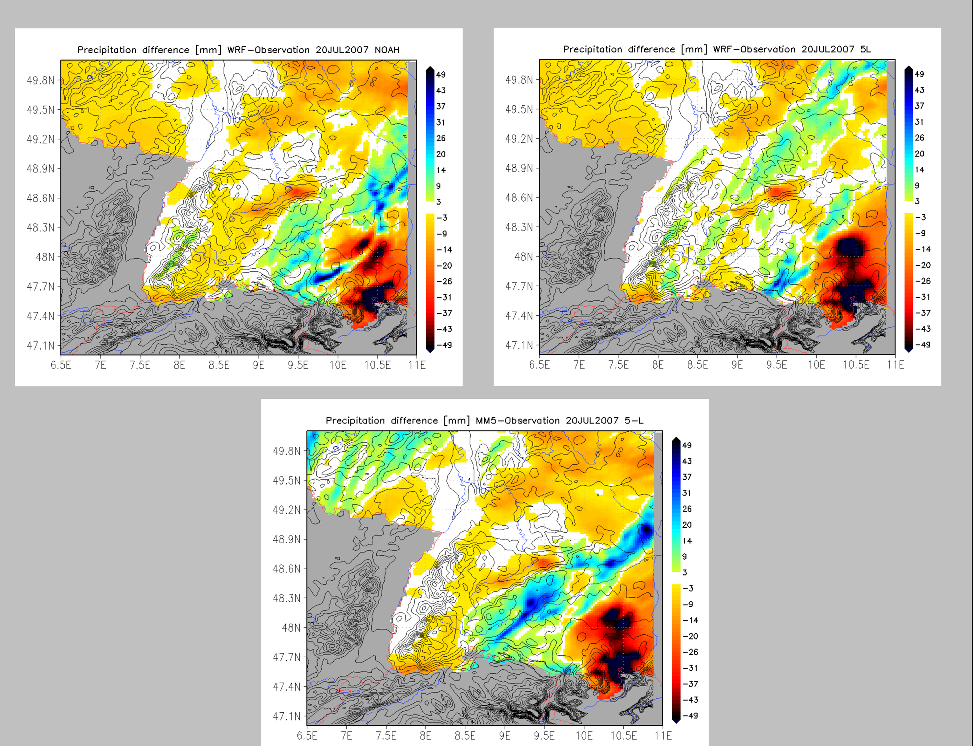

Figure 9: 24h precipitation differences of IOP 9c compared to REGNIE.

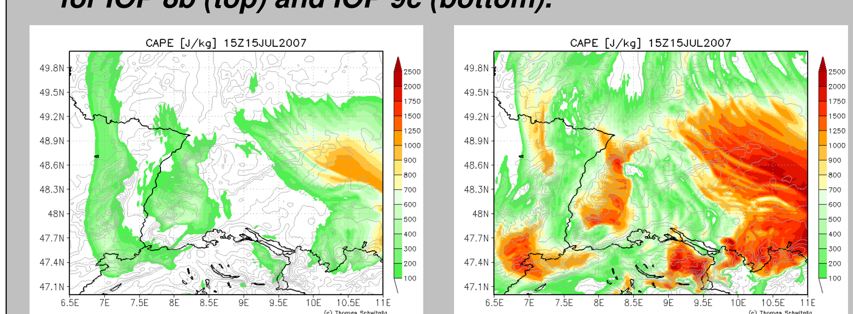

Figure 10: WRF CAPE values for IOP 8b with the 5-layer soil model (left) and NOAH-LSM (right).

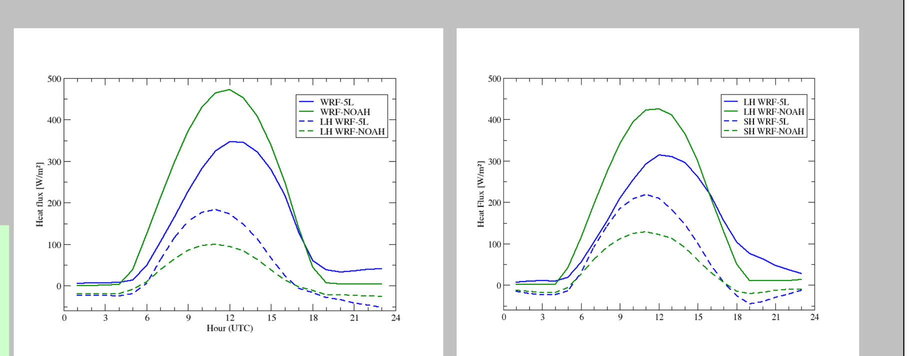

Figure 11: Domain averaged diurnal cycle of latent (LH) and sensible (SH) fluxes of IOP 8b (left) and IOP 9c (right).

- Both models had problems simulating 2m humidity with the 5-layer soil model (also observed during other studies) – result of wrong moisture initialization or a PBL problem?
- Use of NOAH-LSM weakened this problem
- WRF tended to overestimate 10m wind speeds starting 18UTC
- On cloud free days both MM5 and WRF underestimate 2m temperatures
- Much higher CAPE values were simulated when using the NOAH-LSM instead the of 5-layer soil model

Runs with the NOAH-LSM show much higher latent heat fluxes during daytime and thus reduced sensible heat fluxes. This leads to lower 2m temperatures as seen in Figure 8 and to higher instability (see Fig. 10).

Future Plans

During the next two years we focus on the extension and improvement of the assimilation system. This includes the transition from MM5 to WRF as the working horse. This system will be used to perform high-resolution impact and process studies for selected COPS IOPs. The aim is to understand the processes evolving in the model and finally try to improve the model physics (e.g. boundary layer and cloud microphysics).

The assimilation system currently available for the WRF model shall be extended to use observations of scanning lidar systems and radial velocities of the German Weather Service (DWD) radar network (see poster of Hans-Stefan Bauer and talk of Florian Zus).

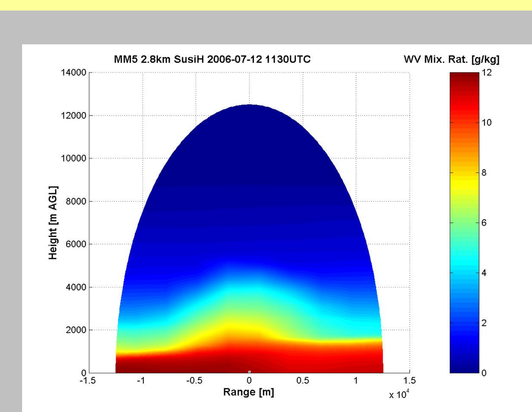

Figure 12: Lidar water vapor mixing ratio [g/kg] derived from MM5 model output using the forward operator for scanning lidar systems.

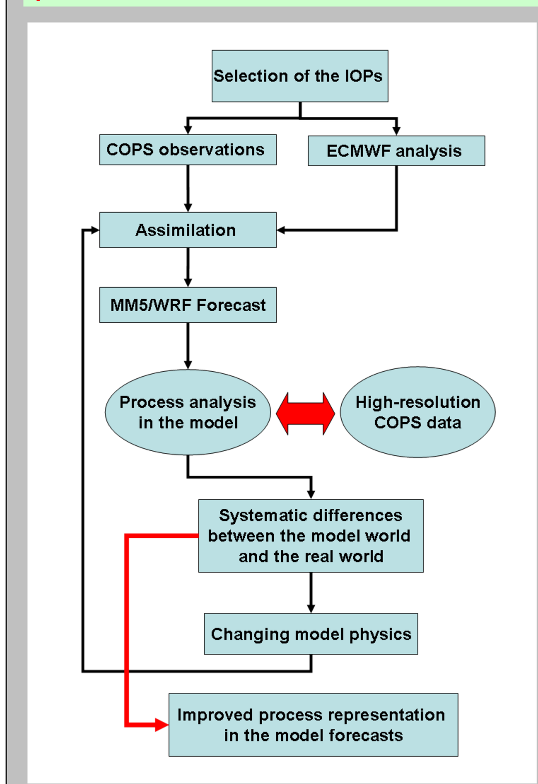

Figure 13: Steps to be carried out for the high-resolution process studies

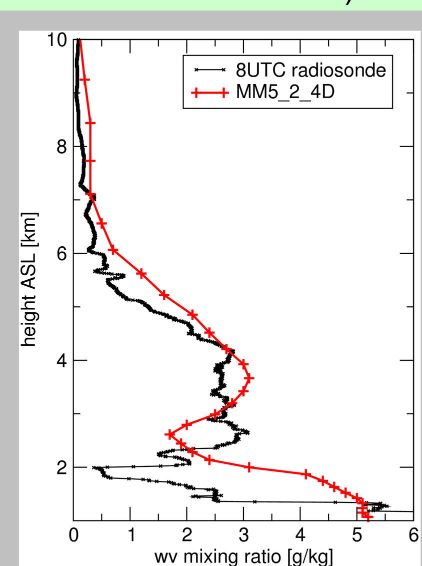

Figure 14: Comparison of a radiosonde launched at Supersite Hornisgrinde with the MM5 profile of the corresponding grid box.

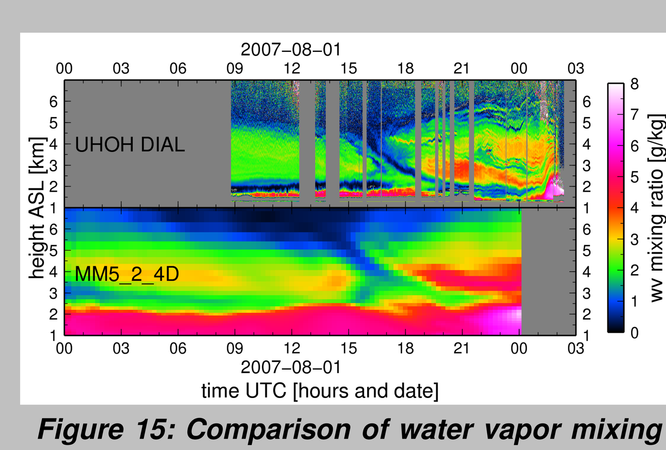

Figure 15: Comparison of water vapor mixing ratio measured by the UHOH DIAL system (top) and the free forecast based on the MM5 4DVAR initial state (bottom).

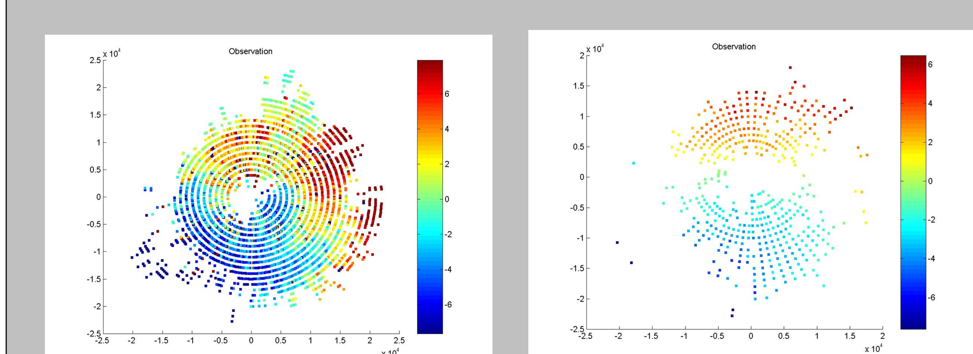

Figure 16: Example of Radar radial velocity of the DWD Radar at Feldberg (BF) (left panel) and remaining data after data thinning and quality checking against the ECMWF background (right panel).

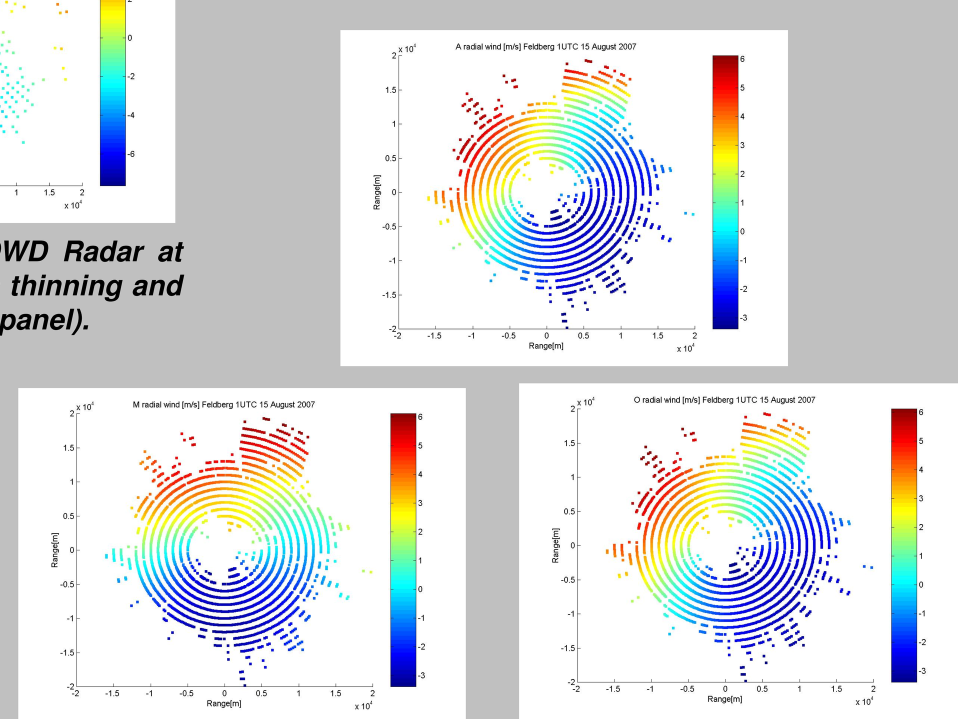

Figure 17: Example of the performance of the radar radial velocity operator developed for the MM5 4DVAR. The left panel shows the radial velocity of the model and the right panel an artificial radar scan at the location of the Feldberg Radar. In the upper panel the result after the assimilation of the artificial radar scan is shown. The radar operator for radial velocity and reflectivity is already available in the WRF 3DVAR/4DVAR system.

Contacts: Thomas Schwitalla and Hans-Stefan Bauer, Institute of Physics and Meteorology, University of Hohenheim, Garbenstrasse 30, 70599 Stuttgart, Germany schwital@uni-hohenheim.de, hsbauer@uni-hohenheim.de